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EXTENSIVE USE OF ISOTOPE HYDROLOGY FOR WATER RESOURCES MANAGEMENT

Report by the Director General to the Board of Governors and the General Conference

I. Introduction

1. The 40th regular session of the General Conference, in 1996, had before it a report (GC/2854-GC(40)/3) submitted on the progress and achievements in extensive use of isotope hydrology for water resources management pursuant to the request made by an earlier resolution (GC(39)/RES/16).

2. The General Conference in 1996 also adopted resolution GC(40)/RES/15, which requested "the Director General to integrate the available expertise and resources of the Agency and Member States and to direct them towards concrete programmes for producing a visible impact by improving the quality and availability of water". It also requested the Agency to make efforts at the national and international level to ensure that isotope hydrology forms an integral part of water resources management; to identify and upgrade selected laboratories in Member States to the level of regional laboratories so as to provide easy access for field hydrologists; and to take steps, along with concerned United Nations agencies, to introduce isotope hydrology into the university curricula of Member States. It also reiterated the request for the Agency to continue to explore the possibility of working with other concerned international organizations and solicit their technical and financial co-operation.

3. The present document provides, as requested by resolution GC(40)/RES/15, an overview and highlights of initiatives taken relevant to the above requests and future action planned in this regard. It is being issued for the attention of both the Board of Governors and the General Conference.

97-02772

II. Programme overview

4. A detailed review on the progress and achievements made in implementing the Agency's programme component in water resources, was provided in the 1996 report GOV/2854-GC(40)/3. This document is therefore focused on specific requests addressed in the General Conference resolution GC(40)/RES/15, and thus includes highlights of recent efforts and some examples demonstrating the end user benefit of recently concluded activities in isotope hydrology and their impact on water resources assessment and management practices.

5. The Agency's 1997-1998 programme on "Development and Management of Water Resources" was re-oriented to incorporate greater focus on specific areas of high priority for water resources management. These initiatives are geared towards enhancement of the socio-economic impacts of isotope hydrology activities. In addition to the seven operational Coordinated Research Programmes (CRP) currently being implemented, a number of new tasks related to impact of urbanization on water resources, water pollution in surface waters, and soil erosion and reservoir siltation, are being initiated. Since 1996, six Research Coordination Meetings have been held, two CRPs completed and two new CRPs initiated. The results obtained and methodologies further developed through the completed CRPs are also being integrated into the implementation of ongoing TC projects.

6. The enhanced efforts made during the last years towards more extensive use of isotope hydrology for water resources development and management, are manifested by a considerable increase in the support provided to the technical cooperation programme (Annex-1) and by the provision of training (Annex-2). The number of technical cooperation (TC) projects in isotope hydrology applications has been steadily increasing in response to requests made by the Member countries and 160 TC projects in 63 countries with a total budgetary allocation of US $20 million have been implemented over the last ten years to facilitate effective application of isotope methods in the water sector and to develop national capabilities in the application of isotope hydrology.

7. In 1996, 58 TC projects in 43 countries including 3 Model Projects were operational. Twelve national TC projects were completed by mid-1997. Similarly, the regional project ARCAL XVIII, in which six countries (Brazil, Chile, Costa Rica, Cuba, Mexico and Venezuela) were involved in the use of tracer techniques to study dam leakage, was concluded at the end of 1996. Subsequent to the appraisals of TC project proposals for the 1997/98 cycle, nineteen new national TC projects have been approved by the Board of Governors in the field of isotope hydrology. At present, a total of 65 TC projects are operational with a budgetary allocation of US $ 2.7 million.

8. Examples of recent achievements in TC activities in isotope hydrology are given below.

a) The regional project RLA/8/018 "Tracer techniques in dam leakage" (ARCAL XVIII), aimed at developing national capabilities in applying tracer techniques to identify the origin of water leakage in dams and reservoirs, was successfully concluded in 1996. The project started with the participation of Brazil, Costa Rica, Cuba and Mexico. Later, Venezuela and Chile were included. Leakage problems were studied in nine reservoirs for drinking water

supply, irrigation and/or electricity generation. In a few cases where leakage was found to be related to the water from the reservoir, corrective measures were suggested to the local authorities in charge of reservoir management and maintenance. In no case was the dam structure endangered by the leakages. It was estimated by the counterpart national institutes of the project that savings in excess of US $ 6 million were achieved as a major outcome of the project, since substantial exploratory investigations based on conventional engineering approaches which were scheduled initially were eliminated as a result of the findings of isotope applications.

b) The model project ELS/8/005 "Isotope Hydrology and Geochemistry in Geothermal Fields", successfully completed in 1996, resulted in a hydrological evaluation of the Berlin and Ahuachapan geothermal fields, enabling the end user, Comisión Ejecutiva Hidroelectrica del Río Lempa (CEL), to formulate strategies for geothermal energy utilization as well as for the disposal of waste water through re-injection. Based on the supplementary data and results obtained from isotope studies, ten production wells will be drilled in the next two years at Ahuachapan field, while re-injection will take place in Chipilapa. Expansion activities are intended to increase electricity generation from 55 Mwe to 165 Mwe by the year 2000. The project, therefore, had a visible impact on the energy, science and technology sectors of the country.

c) As a follow-up to the achievements made in the four countries involved in phase I of the Model Project Regional Africa (RAF/8/022), phase II of the project was started at the beginning of 1997, with the addition of Algeria, Mali, Niger, Nigeria and Sudan. During the first phase of the project, detailed field investigations in two study areas were conducted in Egypt to make an assessment of the groundwater resource availability and recharge occurring from the Nile river to the adjacent aquifer systems. These results will permit further land reclamation in the region studied. Investigations conducted in the Moyale region of Ethiopia enabled identification of renewable groundwater resources and estimation of the renewal rate as well as mapping of non-renewable resources available for exploitation. Studies completed in the Tafilalt region in Morocco regarding groundwater dynamics resulted in management decisions to close five artesian wells for sustainable utilisation of the aquifer. Optimum areas for artificial recharge have been delineated based on the isotope field investigations conducted in the Guelmim region in Morocco, which will improve the drinking water supply in the region.

III. Initiatives taken and actions planned

Integration of isotope hydrology techniques into water resources development practices and management:

9. Nuclear applications in the water sector require close cooperation and joint action by national institutions with the necessary expertise and analytical capability in the methodologies (often these are national nuclear research centers) and institutions directly in charge of the development of water resources and routine operation of water related services (end users of the technology). To further develop manpower in the field of isotope hydrology in Member States, six training courses were accomplished in 1996: one inter-regional training course held in Vienna, and 5 regional training courses (China, Chile, El Salvador, Mexico and

Morocco). The courses included a total of 104 participants from 50 Member States and covered subjects ranging from groundwater resources evaluation, groundwater dynamics, water contamination and mathematical modelling, geothermics, and application of artificial tracers.

10. In this regard, more emphasis would need to be given to increase the end users' awareness of these techniques and their contributions to water resources, to enable more effective integration of isotope methods into overall water resources management practices. For this purpose, the following specific meetings have been included in the 1997 programme:

- Interregional meeting on integration of isotope field investigations into large-scale water projects in water scarce areas, scheduled to be held in Rabat, Morocco from 8 to 12 September, 1997, in which specialists from 20 Member countries in arid regions are expected to participate.

- Regional meeting for Latin America on effective water resources management - need for integration of isotope field investigations to be held in Lima, Peru, in November 1997, in which specialists from eight Member countries from the region will be participating.

- Regional meeting for West Asia on effective water resources management - need for integration of isotope field investigations to be held in Amman, Jordan, from 5 to 8 October, 1997, with the expected participation of specialists from 12 Member countries from the region.

- A similar meeting is planned to be held for Africa in 1998.

11. The participants in the above cited meetings will be senior management staff from national institutions who have direct responsibility in water resources development and management and water related services. Specific lectures on isotope methods and their contribution to various aspects of resource development and management, and hydro-engineering applications, both in surface and groundwater systems, will be provided and the results of selected case studies will be presented. The workshop will bring together specialists in isotope technology and the senior staff of end-user national institutions, as a basis for establishing a link between them to accelerate the integration of nuclear techniques into water resources management practices at the national level and to facilitate cooperation on issues of mutual interest at the regional level. These meetings will also serve as a basis for identifying priority areas in water resources as formulated by the end-users, so that future programmes of the Agency can be designed according to the concept of thematic planning focused on actual practical needs of the countries and regions.

Provision of analytical services to Member States and strengthening of laboratories in isotope hydrology:

12. Technical support in establishing and/or strengthening analytical capabilities required for specific isotope analyses related to applications in the water sector of Member States are an integral part of the Agency's Programme in Isotope Hydrology. Through technical co-operation activities, the Agency has over the years established or upgraded isotope hydrology laboratories in 42 Member States, as shown in Annex-3. This support has considerably enhanced the use of isotope methods in applied research and practical applications in the water and environment sector in those countries.

13. Since the last report, further assistance has been provided to upgrade and establish analytical facilities in thirteen Member countries. In Egypt, an existing isotope hydrology laboratory was upgraded through the provision and installation of a liquid scintillation counter and the necessary preparation lines for analysis of ^{14}C and tritium. Thus, this laboratory is now able to carry out the complete set of isotope analyses necessary for isotope hydrological investigations. Liquid scintillation analysers with preparation lines for tritium analysis in water samples were provided to Syria, Zimbabwe and Tanzania. In the latter two countries, complete new isotope hydrology laboratories were established through TC support, with the capability of carrying out high precision tritium analyses, taking into consideration the low tritium activities in water reservoirs in the southern hemisphere and in low latitudes. In Zimbabwe, as well as in Paraguay and in the Dominican Republic, additional equipment necessary for ^{14}C analyses using the liquid scintillation technique is being installed. In Lebanon, Venezuela, Niger and Morocco, equipment for chemical analyses and for application of nuclear dating techniques was provided. In Mexico and Costa Rica, gas chromatographs for chemical investigations complementary to isotope measurements for geothermal applications were installed.

14. An isotope laboratory was recently established in El Salvador under technical co-operation project ELS/8/004, "Isotope Hydrology in Geothermal Fields". A mass spectrometer makes it possible to analyse oxygen-18 and deuterium on the spot, without the assistance of overseas laboratories. In addition, this stable isotope laboratory will also be able to extend its services to the water resources sector, for the development and management of the water supply as well as to monitor the hydrological problems associated with surface water resources of the country. Furthermore, it will provide analytical services for geothermal applications to other countries in Central America where geothermal energy production will rise in the next five years, e.g. Costa Rica and Guatemala.

15. In view of the large capital investment involved in establishing isotope hydrology laboratories and the basic infrastructure required for their long-term routine operation, initiatives have been taken to maintain efficient use of these laboratories. In this regard, already existing national laboratories will be strengthened in terms of maintaining a high analytical quality as well as using their experience and expertise for TC projects in other countries of the region. As a first step, inter-laboratory comparison exercises are being prepared to identify the laboratories with adequate performance in the analysis of stable isotope ratios of hydrogen and oxygen in water samples. This inter-laboratory comparison will be followed up by an expert service assignment to the selected laboratories to discuss the

results, to assess their analytical procedures in terms of analytical quality requirements, and to deliver lectures on the state of the art of quality assurance in the Agency Isotope Hydrology Laboratory as a reference laboratory. In cases of inadequate analytical performance, further support to improve their capability will be considered. In order to keep the performance level in the participating laboratories as high as possible, further analytical performance tests, organized by the Agency Isotope Hydrology Laboratory, are planned to be carried out regularly .

16. Through the Agency's activities related to analytical services and quality assurance, the Agency's Isotope Hydrology Laboratory distributes standards and reference material, and will continue to conduct inter-comparison studies. About 400 units of stable isotope reference material are provided every year to customers and laboratories in Member countries. In follow-up of a consultants service on IAEA reference materials, the existing materials were reviewed and specific improvements of international quality assurance activities in this field were initiated. In 1996, two new reference materials for mass spectrometric analysis of sulphur isotopes were prepared and tested. Five new materials are in preparation and will be tested with regard to homogeneity and suitability as reference materials. The Isotope Hydrology Laboratory is producing three of them and is involved in the testing of two of the other materials. In addition, a first draft of quality assurance guidelines for the operation of isotope hydrology laboratories was prepared, which is expected to assist all existing laboratories in maintaining high quality analysis.

17. A series of measures have been taken since 1996 to further strengthen the capabilities of the Agency' Isotope Hydrology Laboratory as a reference laboratory of the Member countries for the analysis of environmental isotopes. To this end, the precision of the measurement of stable isotopes in water samples was further improved, and the sensitivity of the detection of the radionuclides tritium and radiocarbon was increased in line with presently accepted international levels of precision/sensitivity. Further, a field sampling method for isotopic investigations of atmospheric water vapour was developed and successfully tested.

Incorporation of Isotope Hydrology into University Curricula:

18. The Agency's efforts in terms of training courses, workshops and seminars have so far been the main avenue for the required human-resources development in the Member States as regards isotope hydrology methods and their applications in a wide variety of hydrological problems in water resources and hydro-engineering. Furthermore, the Agency has been providing lectures in this specific field at international post-graduate level courses on hydrology which are sponsored by UNESCO within their educational activities related to water resources.

19. Isotope Hydrology, including nuclear applications in the water resources sector as a whole, is now an established scientific discipline and thus the Agency will be taking steps towards providing to teaching institutions in Member States a series of well designed reference teaching materials to introduce this discipline into their curricula at the undergraduate and/or graduate level. This teaching material will cover the essential theoretical concepts, methodologies of applications, data evaluation and interpretation approaches. The

Agency, in cooperation with UNESCO, has recently initiated steps to issue teaching material in isotope hydrology, and actions are being taken for the preparation of such teaching material during 1997/98.

20. The contents of a series of chapters (as individual books or manuals) dealing with theory and applications of environmental isotopes in hydrology have already been designed, and their preparation has been entrusted to designated coordinators and contributing authors. Final manuscripts are expected to be completed during 1998. UNESCO will be publishing this series of chapters in the form of "Technical Reports in Hydrology" and they will be widely distributed to teaching institutes and universities by UNESCO and the IAEA. The material will also be used in training courses organized by the Agency and by other organizations.

IV. Cooperation with other organizations

21. In continuing efforts to establish closer collaboration with governmental and non-governmental organizations in the field of isotope hydrology, special emphasis was placed on activities related to cooperation with UNESCO and WMO. The ongoing International Hydrology Programme of UNESCO and the Operational Hydrology Programme of WMO are two major international scale projects of specific relevance for enhancing the incorporation of isotope methodologies into regional and international programmes on water and the environment. Further steps undertaken during the review period towards closer collaboration with these organizations are outlined below.

22. As priority areas for the collaboration between IAEA and UNESCO, three main themes were identified: sedimentation processes in reservoirs and delta areas, role of unsaturated zone processes in groundwater quality and water resources assessment in arid and semi-arid zones. There are indications that UNESCO is willing to provide funds to the Agency for incorporating isotope methodologies into the implementation of their new regional projects in arid zones related to "Wadi Hydrology" and "Groundwater Protection". Specific activities in all these fields which are of mutual interest to both organizations are being defined and will be implemented through further contacts between the Secretariats.

23. WMO, through its programme on "Operational Hydrology", will strengthen its cooperation with the Agency in the fields of water pollution, groundwater modeling, monitoring of natural and artificial recharge to aquifers (particularly in arid regions), and use of general circulation models to predict changes in hydrological regimes due to impact of climate change. Joint activities involving meetings, preparation of practical guidance material and field demonstration studies on these issues will be planned through consultations of the Secretariats of both organizations.

24. During 1996, further steps to strengthen the operation of the Global Network for "Isotopes in precipitation (GNIP)" were taken. A Memorandum of Understanding was elaborated between the World Meteorological Organization (WMO) and the Agency, describing the operational aspects, commitments of the parties, and legal aspects of cooperation. The Memorandum of Understanding is aimed at ensuring the continuity of the operation of the Network and the active involvement of the two signatories as well as the other scientific communities concerned, including the International Geosphere-Biosphere

Programme (IGBP) and the World Climate Research Programme (WCRP), in supporting the further development of the Network and the multidisciplinary use of its database. In this regard it should be noted that a home page on GNIP associated with the GNIP database has been included in the Internet so that users can access the data for their use in hydrological and related environmental and climatological studies. According to recent statistics, the GNIP homepage and database is being visited about 200 times per month by users worldwide.

25. Initiatives were also taken to involve other international scientific organizations in the implementation of the Agency's programme on water resources, in particular the International Committee on Tracers (ICT) of the International Association of Hydrological Sciences (IAHS). The ICT, mainly involved in activities directed towards information exchange on tracer applications in hydrology, including use of isotopes, indicated their preparedness to sponsor the Agency's International Symposium on Isotope Hydrology scheduled for 1999, through providing specialists to cover selected topics in hydrology and critical assessment of isotope methods by invited key-note papers. Furthermore ICT will also contribute to the establishment and maintenance of the Global Isotope Hydrology Database through providing data from their national counterparts.

26. The activities started in 1995 towards strengthening cooperation with other UN organizations in water resources development and management were followed up through contacts with various organizations and have, in two cases, resulted in the commencing of joint activities. These include UNESCO's contribution to the Agency's initiative to prepare a textbook on Isotope Hydrology, and the support provided by the UN Economic Commission for Africa (UNECA) to the implementation of the IAEA Regional Model Project for Africa by hosting the regional expert for this project.

27. More effective use of nuclear science and technology to produce a visible impact on the water sector of Member countries will require joint planning and design of activities among concerned organizations dealing with water resources. But, little progress with respect to joint actions has been made so far, one of the reasons being that most of these organizations focus on the development of scientific methodologies and the coordination of national and international programmes rather than on operational activities related to the implementation of applied field projects. It should be noted, however, that at the 1996 meeting of the ACC Subcommittee on Water Resources, where all of these organizations were represented, a commitment for joint actions was made, starting with an exchange of information on programmes and activities of each organization in different African countries. The forthcoming meeting of the ACC Subcommittee in October 1997 at the Agency's Headquarters will provide the appropriate forum to follow up on these matters.

V. Outlook

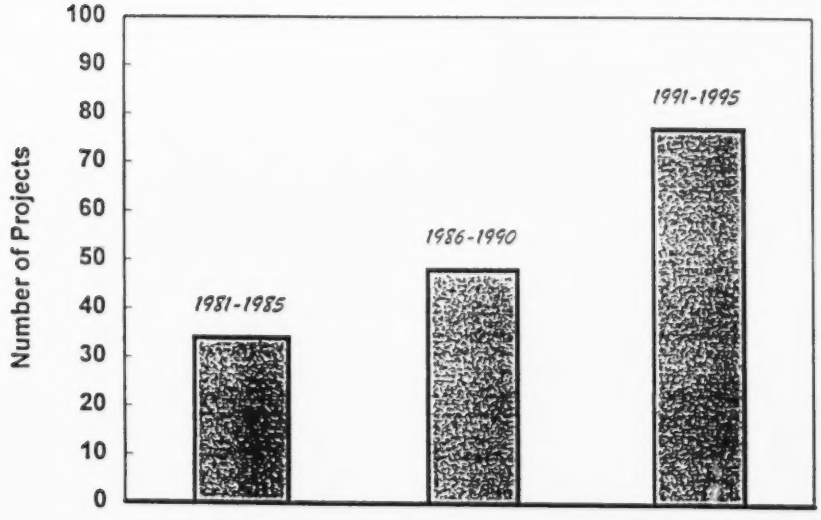
28. The future programme is conceived as a consolidation of the ongoing activities which have been designed in response to the current major challenges in hydrology and water resources, namely:

- human impact on water resources,
- water resources in areas of water scarcity, and

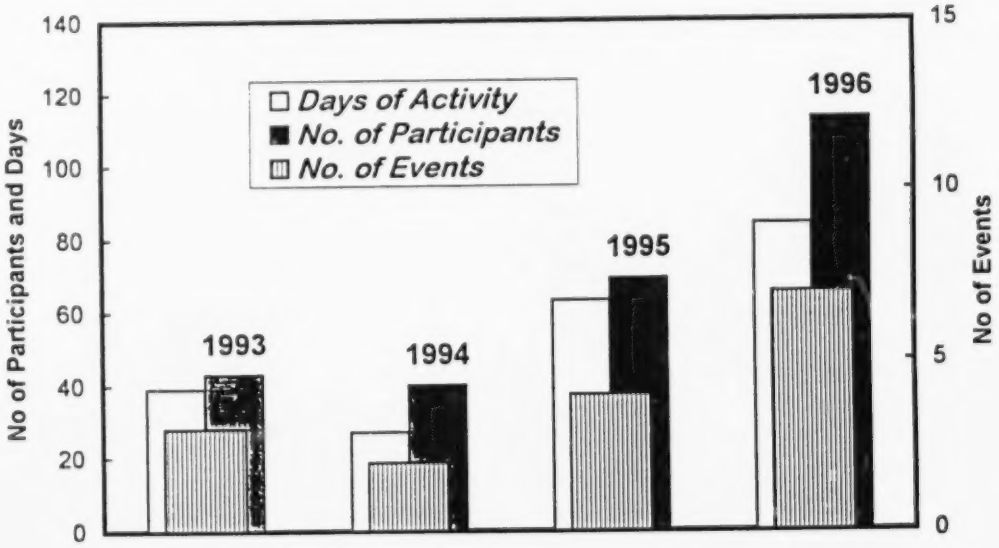
- hydroclimatic changes.

29. The programme will include the use of isotopes in assessing (i) human impact on the quality of drinking water, (ii) groundwater salinization in water scarce areas, (iii) response of fluvial systems to changes in land cover and climate, and (iv) processes involved in the migration of trace constituents in groundwater. Emphasis will be put on the establishment of an isotope hydrology database, a necessary activity to improve data acquisition and for reporting in isotope hydrology and related fields. The database is planned to be combined with the Geographic Information System (GIS) to facilitate efficient and wide-spread use of the database in Member countries. A number of activities will be related to the development and implementation of a quality assurance system for isotope analysis. Support to Member States will be provided through the technical co-operation programme in accordance with the needs, in the fields of groundwater pollution, with special regard to the drinking water supply to major urban areas, water resources assessment and management in areas of water scarcity, hydrological aspects of geothermal activities in Member States, and the assessment of surface water resources.

IAEA TECHNICAL CO-OPERATION PROJECTS IN ISOTOPE HYDROLOGY (1981-1995)



IAEA Training Courses, Workshops and Seminars in Isotope Hydrology



Isotope Hydrology Laboratories installed/upgraded with assistance of IAEA